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Contribution to the knowledge of dragonflies (Odonata) from the Raja Ampat (Indonesia), with notes on their ecology

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Mārtiņš Kalniņš [1, 2]

1 – Department of Biosystematics, Institute of Life Sciences and Technology, Daugavpils University, Vienības iela 13, LV-5401, Daugavpils, Latvia; martins.kalnins@biology.lv
2 – Joint Stock Company “Latvia's State forests”, Vaiņodes iela 1, LV-1004, Rīga, Latvia

Abstract: This article contains information on 103 Odonata species from Raja Ampat – Waigeo, Misool, Salawati, and Batanta Islands. No information was found on the species composition of Kofiau dragonflies. Eleven Odonata species are new to the fauna of Misool Island, collected or observed by the author and five Odonata species found by other researchers. Three Odonata species are new records for the fauna of Waigeo Island. Additional information on ecology and behaviour of several species is also given.

Key words: Odonata, dragonfly, fauna, Raja Ampat, Wallacea, Papua, Indonesia.

Introduction

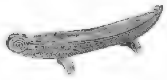
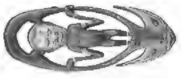
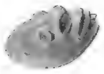
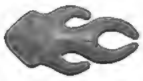
The Raja Ampat, or the *Four Kings*, is an archipelago comprising over 1500 small islands, cays, and shoals surrounding the four main islands of Misool, Salawati, Batanta, and Waigeo, and the smaller island of Kofiau. Administratively, the archipelago is part of the province of West Papua (formerly Irian Jaya) in Indonesia. The Raja Ampat archipelago straddles the Equator and forms part of the Coral Triangle. The islands are part of the Vogelkop-Aru lowland rainforests ecoregion. Generally, this ecoregion exhibits low to moderate richness and endemism compared with those of other ecoregions in Indo-Malaysia. The surface geology of this ecoregion is composed predominantly of sedimentary rock and recent alluvium, with some large areas of limestone or ultramafic near Sorong and on Waigeo and Misool islands (Wikramanayake *et al*. 2002).

Waigeo, also known as Amberi, or Waigiu, has an area of 3155 km² and its highest point is 958 m. The town of Waisai in the east of the island is the capital of the Raja Ampat Regency. According to remote sensing data (cf. Google Earth, Sentinel), most of the island is covered by primary lowland rainforests. Due to relief hardly accessible, Waigeo is still 70–80% covered by dense pristine rainforests. The largest settlements and areas of human impact are on the north coast of the island.

Misool, formerly spelled Mysol (Dutch: Misoöl) or Misol has an area of 2034 km². In some sources Misool is also called Batanme (Anonymous 2004). The highest point is 561 m and the main towns are Len Malaas, located on the island’s northern coast and Lilinta (Lelintah), located on the island’s south coast (some maps, such as the Mapcarta https://mapcarta.com/15621866, incorrectly show the location of Lilinta as about 20 km northwest). According to remote sensing data (cf. Google Earth, Sentinel), most of the island is covered by primary lowland rainforests. Hardly accessible, Misool is still 80–90% covered by dense pristine rainforests and there are almost no roads or active airstrips there. The largest settlements and areas of human impact are on the north coast of the island. While the Western part of the island is mostly formed by basalt formations the eastern part lies on limestone.

Salawati has an area of 1623 km². Salawati is separated from New Guinea to the southeast by the Sele Strait (Galowa Strait, Revenges Strait), and from Batanta to the north by the Pitt Strait (Sagewin Strait). According to remote sensing data (cf. Google Earth, Sentinel), most of the island is covered by primary lowland rainforests, although the island, including its central part, has a relatively well-developed road network and a relatively large number of settlements.

Batanta has an area of 453 km² and its highest point is 1184 m. The Pitt Strait separates it

from Salawati, while the Dampier Strait (Augusta's Strait) separates it from Waigeo. According to remote sensing data (cf. Google Earth, Sentinel), most of the island is covered by primary lowland rainforests. Hardly accessible, Batanta is still 80–90% covered by dense pristine rainforests and there are almost no roads or active airstrips there. The largest settlements and areas of human impact are on the coasts of the island.

Kofiau has an area of ~180 km² and its highest point is 255 m. The island is primarily raised coral limestone with some volcanic hills. According to remote sensing data (cf. Google Earth, Sentinel), at least 70% of the island is covered by primary lowland rainforests, but the W part of the island, the N coast and the small islands are affected by human economic activities – coconut plantations have been established there.

Information about dragonflies in Raja Ampat can be found mainly in Lieftinck's publications (Lieftinck 1948; 1971 etc.). The first work to provide details of all the dragonflies and damselflies found in Batanta, Misool, Salawati and Waigeo is the work of John Michalski (2012), although a checklist of dragonflies for each island was not provided in this work. Over the last few years, two works have been published with a checklist of damselflies (Kalkman & Orr 2013) and dragonflies (Orr & Kalkman 2015) recorded from New Guinea and the adjacent islands. Among these 17 Zygoptera species and 12 Anisoptera species are identified for the Odonata fauna of Waigeo, 13 Zygoptera species and 16 Anisoptera species are identified for Misool, and 9 Zygoptera species and 12 (one more species mentioned as possible) Anisoptera species were listed for Batanta and Salawati (together). Tibor Kovács has published four works (Kovács *et al*. 2015a & b; 2016; 2021), in which 24 Zygoptera species and 37 Anisoptera species (and *Metagrion* sp. not identified to species level) have been identified for Batanta Island (including Arefi and Birie Islands).

New data became available on the Misool and Waigeo dragonfly fauna since the publication of the above-mentioned checklists, both published (cf. Theischinger & Kalkman 2014a & b) and unpublished; the purpose of the present paper is to provide an updated checklist of the Odonata of Raja Ampat Islands.

Material and methods

Data on dragonflies were obtained mainly from the author's personal observations on dragonflies in Misool (including a single observation from adjacent Polee islet) and Dmitry Telnov's observations from Misool and Waigeo. Both field and hand identification was performed. The processed material covers several observation sites in Misool and three in Waigeo (Maps 1–3). The following abbreviations (key words of localities of the species) are used in the description of the material:

Aduwey – 28.03.2009 and 30.03.2009 Misool SW, Aduwey (Aduai) vill., 01°59'4"S, 129°54'32"E, village, gardens, bushes & small ditches or pools;
Biga - 03.02.2012 Misool S, Biga vill. ~7,5 km W, River Biga valley, 02°01'23"S, 130°12'38"E, primary lowland forest on limestone;
Gam – 03.04.2009 Misool SE, Lilinta (Lelintah) vill. ~13 km NW, Gamta vill. ~11 km NWW, River Gam valley, 01°57'49"S, 130°11'10"E, primary lowland forest;
Gam* – 04.-05.02.2012 Misool (central), Gamta vill. 12-14 km NW, River Gam valley, 01°57'50"S, 130°11'09"E, primary lowland rainforest on limestone;
Hakau 1 – 25.03.2009 and 27.03.2009 Misool SW, Aduwey (Aduai) vill. ~3 km NNW, valley of River Hakau, 01°57'22"S, 129°54'43"E, near river, in a primary lowland forest;
Hakau 2 – 29.03.2009 and 31.03.2009 Misool SW, Aduwey (Aduai) vill. ~1,5 km NNW, valley of River Hakau, 01°58'21"S, 129°54'30"E, in lowland forest/forest gardens (Fig. 1);
Ifeylo – 26.03.2009 Misool SW, Aduwey (Aduai) vill. ~4 km NNE, valley of River Ifeylo, 01°57'49"S, 129°56'17"E, near river in primary lowland forest;
Lilinta – 01.-02.04.2009 Misool SE, Lilinta (Lelintah) vill. env., 02°02'47"S, 130°16'7"E, secondary lowland forest;
Polee – 02.04.2009 Misool S, Lilinta (Lelintah) vill. ~16 km S, Polee Island, 02°11'56"S, 130°16'19"E, primary lowland forest;
Vanlal – 03.04.2009 Misool SE, Lilinta (Lelintah) vill. ~14 km NW, Gamta vill. ~9 km NWW, River Vanlal valley near the waterfall, 01°57'17"S, 130°13'47"E;
Waisai 1 – 16.-17.02.2012 Waigeo, Waisai 2-3 km W, 00°25'40''S, 130°47'36''E, secondary lowland rainforest on limestone;
Waisai 2 – 16.02.2012 Waigeo, Waisai 10-13 km NE, 00°21'17''S, 130°54'37''E, primary lowland forest, limestone creek;
Waisai 3 – 17.02.2012 Waigeo, Waisai 4-6 km (around Waisai airport), 00°24'46''S, 130°44'11''E, coastal lower bog.

Dragonflies from Raja Ampat region were also searched for on the insect trader website, Insect-Trade.EU (https://www.insect-trade.eu). Specimens were not purchased, but the information available on the website was used – in particular, the image (for species identification) and its locality.

The term "Papuan Region" (or in the strict zoogeographic sense – the Papuan subregion of the Australian Region) is often listed in zoological or zoogeographic literature, but sometimes extended to different areas. Therefore, for the purposes of this work, the definitions as explained in the literature (e.g., Greķe & Telnov 2014) – Papuan Region *sensu lato* and *sensu stricto* – have been used (Map 4).

Results

Brackets after the reference indicate the location of the species only in the Raja Ampat Archipelago. Papers indicating that the species is found in the surrounding islands of New Guinea, without specifying specific sites, are not cited.

Zygoptera Selys, 1854
Argiolestidae Fraser, 1957

***Argiolestes australis* Guerin, 1832**
Kalkman & Orr (2013) Waigeo; Kovács *et al*. (2016; 2021) Batanta; Kalniņš (2017) Waigeo.

Note: An unidentified specimen of *Argiolestes* sp. also known from Misool (Kalniņš 2014).

***Argiolestes varga* Kovács et Theischinger, 2021**
Kovács *et al*. (2021) Batanta.

***Metagrion coartans* Lieftinck, 1956**
Kalkman & Orr (2013) Waigeo.

***Metagrion ochrostoma* Lieftinck, 1949**
Kalkman & Orr (2013) Waigeo.

- ***Metagrion postnodale* Selys, 1878**

Kovács *et al*. (2015b; 2016) Batanta.

Note: All former records of *M. postnodale* from Batanta now refer to *Metagrion* sp. with a remark "more study is needed for the delimitation of this taxon" (Kovács *et al*. 2021).

***Podopteryx selysi* Förster, 1899**
Kalkman & Orr (2013) Batanta, Salawati, Waigeo.

Calopterygidae Selys, 1850

***Neurobasis australis australis* Selys, 1897**
Kalkman & Orr (2013) Batanta, Salawati, Waigeo; Kovács *et al*. (2015b) Batanta, as *Neurobasis australis* s. l., subspecies identification not provided.

***Neurobasis australis misoolensis* Lieftinck, 1955**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool.

Chlorocyphidae Cowley, 1937

***Rhinocypha tincta sagitta* Lieftinck, 1938**
Michalski (2012) Misool; Kalkman & Orr (2013) Batanta, Misool, Salawati; Kovács *et al*. (2015b; 2016; 2021) Batanta, as *Rhinocypha tincta* cf. *sagitta*.
New records: Hakau 1 (12♂ & 2♀), Ifeylo (4♂ & 2♀), Vanlal (2♂).

Note: Common near rivers in primary forest on Misool, one observation – a female laying eggs on a dead branch together with a male guarding them (Fig. 2); only few females observed while males were abundant.

***Rhinocypha tincta tincta* Rambur, 1842**
Kalkman & Orr (2013) Waigeo.

Coenagrionidae Kirby, 1890

***Agriocnemis femina* Brauer, 1868**
Kovács *et al*. (2015b; 2016; 2021) Batanta.
New records: Aduwey (6♂), Waisai 1 (3♂ & 6♀), Waisai 2 (4♂ & 1♀).
First records for Misool and Waigeo.

Note: Numerous specimens observed in Aduwey village, at small ditches with dense, partially submerged aquatic vegetation. During high tide, seawater enters the ditches (Figs 10–11).

***Archibasis mimetes* Tillyard, 1913**
Kalkman & Orr (2013) Batanta, Misool, Salawati, Waigeo.

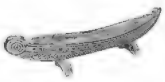
***Argiocnemis rubescens* Selys, 1877**
Kovács *et al*. (2016; 2021) Batanta.

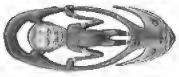
***Ceriagrion aeruginosum* Brauer, 1869**
Kovács *et al*. (2015b; 2021) Batanta.

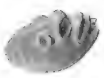
***Ischnura senegalensis* Rambur, 1842**
Kovács *et al*. (2015b; 2021) Batanta.

***Papuagrion magnanimum* Selys, 1876**
Kovács *et al*. (2021) Batanta.

***Pseudagrion civicum* Lieftinck, 1932**
Kovács *et al*. (2015b; 2016; 2021) Batanta.







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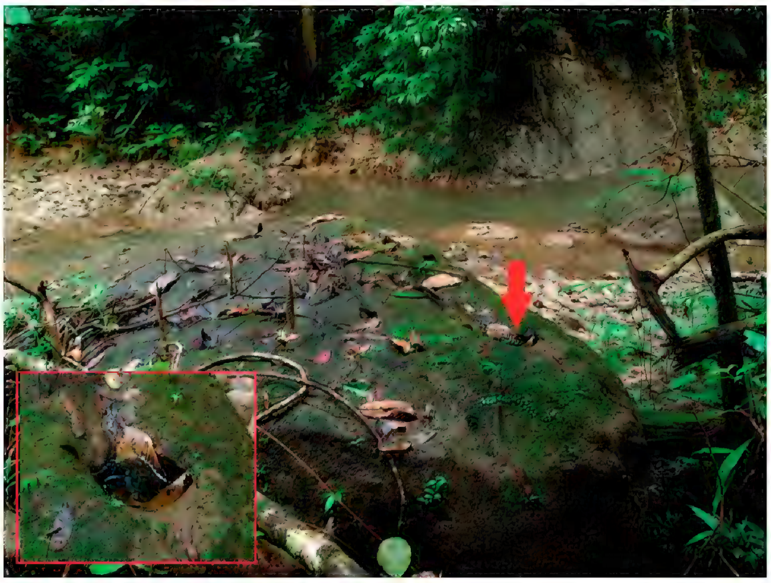

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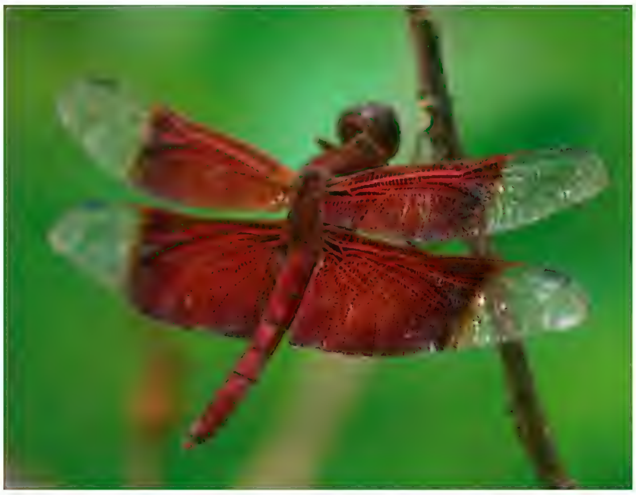

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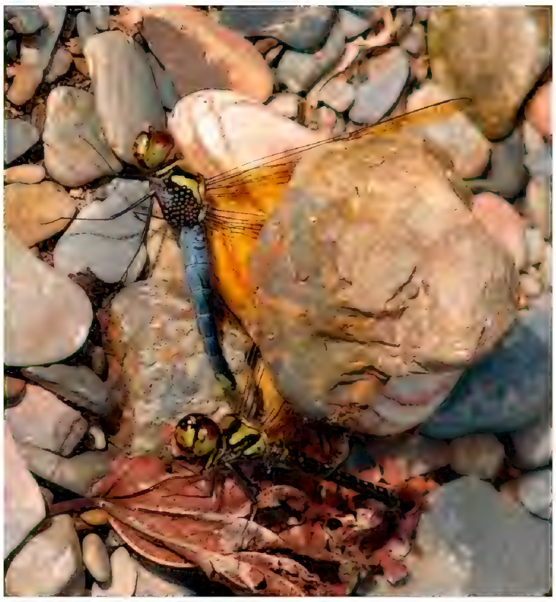

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Figures 1–5. Odonata from Raja Ampat. 1 – Downstream of River Hakau - mosaic landscape with gardens and secondary lowland rainforest and partly dried riverbed - the habitat of adult *Agrionoptera insignis*, *Camacina gigantea, Hydrobasileus brevistylus, Neurothemis stigmatizans,* and *Orthetrum villosovittatum*; 2 – *Rhinocypha tincta sagitta* in Aduwey, Misool, a ♀ (on the left) ovipositing on dead branches partly submerged in the water in a small forest river (stream) and a ♂ (on the right) guarding the ♀; 3 – Place of oviposition of *Agrionoptera longitudinalis* - a small hole in a stone filled with water and some dead leaves; 4 – *Camacinia gigantea* ♂ in Aduwey, Misool. Individual specimens were resting in sunny places between bushes in a mosaic landscape; 5 – *Hydrobasileus brevistylus* in Aduwey, Misool. Pair of specimens observed in copula, resting in a sunny place in a partly dry riverbed between bushes in a mosaic landscape – river valley with gardens and secondary lowland rainforest patches.

***Pseudagrion starreanum* Lieftinck, 1949**
Kalkman & Orr (2013) Batanta, Salawati; Kovács *et al.* (2015b; 2016; 2021) Batanta.

***Teinobasis michalskii* Theischinger et Kalkman 2014**
Theischinger & Kalkman (2014a) Misool.

***Teinobasis prothoracica* Selys, 1877**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool, Waigeo.

***Teinobasis rufithorax* Selys, 1877**
Kalkman & Orr (2013) Batanta, Misool, Salawati, Waigeo; Theischinger & Kalkman (2014a) Misool; Kovács *et al.* (2015b; 2016; 2021) Batanta.
New records: Ifeylo (2♂), Lilinta (1♀).

***Teinobasis superba* (Hagen in Selys, 1877)**
Theischinger & Kalkman (2014a) Misool, as *Teinobasis* cf. *superba*; Kovács *et al.* (2016; 2021) Batanta.

***Teinobasis wallacei* Campion, 1924**
Theischinger & Kalkman (2014a) Misool.

***Xiphiagrion cyanomelas* Selys, 1876**
Kovács *et al.* (2015b; 2021) Batanta.

Isostictidae Fraser, 1955

- ***Selysioneura* cf. *cervicornu* Förster, 1900**
Kovács *et al.* (2015b) Batanta.

Note: Kovács *et al.* (2021) stated that all previous records of *S.* cf. *cervicornu* from Batanta refer to *Selysioneura cornelia*.

***Selysioneura cornelia* Lieftinck, 1953**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool; Kovács *et al.* (2021) Batanta.
New record: Gam (6♂).

***Tanymecosticta jejuna* Lieftinck, 1959**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool.

Lestidae Calvert, 1901

***Indolestes albicaudus* McLachlan, 1895**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool.

Platycnemididae Yacobson et Bianchi, 1905

***Idiocnemis bidentata* Selys, 1878**
Ris (1913) Waigeo; Gassmann (2000) Batanta, Salawati, Waigeo; Kalkman & Orr (2013) Batanta, Salawati, Waigeo; Kovács *et al.* (2015b; 2016; 2021) Batanta.

***Idiocnemis dagnyae* Lieftinck, 1958**
Gassmann (2000) Misool; Michalski (2012) Misool; Kalkman & Orr (2013) Misool.

***Idiocnemis fissidens* Lieftinck, 1958**
Gassmann (1999) Waigeo; Kalkman & Orr (2013) Waigeo.

***Idiocnemis inornata* Selys, 1878**
Kovács *et al.* (2015b; 2016; 2021) Batanta.

***Idiocnemis strumidens* Lieftinck, 1958**
Gassmann (1999) Misool; Michalski (2012) Misool; Kalkman & Orr (2013) Misool; Kovács *et al.* (2016; 2021) Batanta.

***Nososticta atrocyana* Lieftinck, 1960**
Kalkman & Orr (2013) Waigeo; Theischinger & Kalkman (2014b) Waigeo.

***Nososticta aurantiaca* Lieftinck, 1938**
Kalkman & Orr (2013) Batanta, Salawati; Theischinger & Kalkman (2014b) Salawati; Kovács *et al.* (2015b; 2016; 2021) Batanta.

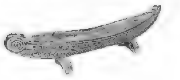
***Nososticta dora* Kovács et Theischinger, 2016**
Kovács *et al.* (2016; 2021) Batanta.

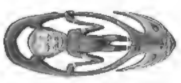
***Nososticta erythroprocta* Selys, 1886**
Kalkman & Orr (2013); Theischinger & Kalkman (2014b) Waigeo.

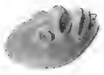
***Nososticta evelynae* Lieftinck, 1960**
Kalkman & Orr (2013) Waigeo; Theischinger & Kalkman (2014b) Waigeo.

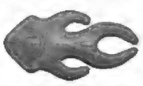
***Nososticta nigrifrons* (Ris, 1913)**
Theischinger & Kalkman (2014b) Misool.

Note: Theischinger & Kalkman (2014b: 221) considered *Nososticta lorentzi* (Lieftinck, 1938) to be a junior synonym of *N. nigrifrons* (Ris, 1913). However, in the abstract of the same paper Theischinger & Kalkman (2014b: 217) listed "*Nososticta nigripes* (Ris, 1913)" presumably for *N. nigrifrons*. The name '*Nososticta nigripes*' was never published and is therefore a *nomen nudum*. Michalski (2012: 154) stated that "*N. lorentzi* appears to be morphologically identical with *N. nigrifrons* (which was originally described from incomplete specimens)". Later on, the same author (Michalski 2012: 155–156) listed both *N. nigrifrons nigrifrons* and *N. nigrifrons lorentzi* as separate









taxa and provided description and drawings of their (rather distinctive!) differential features such as thoracic pattern, colouration of abdominal segments and inconspicuous differences in male abdominal appendages.

***Nososticta plagiata* Selys, 1886**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool; Theischinger & Kalkman (2014b) Misool.
New records: Hakau 1 (3♂ 1♀), Ifeylo 1 (5♂ 1♀), Vanlal (2♂ 1♀), Biga (1♂ & 1♀).

Note: The identification of females is tentative and based on specimens sampled in copula, because no female descriptions are available for any species of this genus.

***Nososticta pyroprocta* Lieftinck, 1960**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool; Theischinger & Kalkman (2014b) Misool.

***Nososticta rufipes* Theischinger et Kalkman, 2014**
Theischinger & Kalkman (2014b) Misool.

***Nososticta xanthe* Lieftinck, 1938**
Kalkman & Orr (2013) Batanta, Salawati; Theischinger & Kalkman (2014b) Misool, Salawati.

***Palaiargia charmosyna* Lieftinck, 1932**
Kovács *et al.* (2016; 2021) Batanta.

***Palaiargia melidora* Lieftinck, 1953**
Kalkman & Orr (2013) Waigeo.

***Palaiargia micropsitta* Lieftinck, 1957**
Michalski (2012) Misool; Kalkman & Orr (2013) Misool.
New record: Gam* (1♂).

***Palaiargia nasiterna* Lieftinck, 1938**
Kalkman & Orr (2013) Waigeo.

***Palaiargia susannae* Kovács et Theischinger, 2015**
Kovács *et al.* (2015b; 2021) Batanta.

Platystictidae Kennedy, 1920

***Drepanosticta auriculata* Selys, 1878**
Kovács *et al.* (2015b; 2016; 2021) Batanta.

***Drepanosticta batanta* Kovács et Theischinger, 2015**
Kovács *et al.* (2015b; 2016; 2021) Batanta.

***Drepanosticta inconspicua* Lieftinck, 1938**
Kalkman & Orr (2013) Waigeo.

***Drepanosticta misoolensis* van Tol, 2007**
van Tol (2007) Misool; Michalski (2012) Misool.
New records: Hakau 1 (4♂ & 1♀), Ifeylo (1♂ (teneral)), Vanlal (1♀).

Note: The identification of females is tentative since one female is a teneral specimen and in bad condition, the second is in normal condition. The original species' description was based on a single teneral specimen (female) with last abdominal segments damaged and distorted (van Tol 2007).

Anisoptera Selys, 1854
Aeshnidae Leach, 1815

***Agyrtacantha dirupta* (Karsch, 1889)**
Orr & Kalkman (2015) Misool; Kovács *et al.* (2021) Batanta.
New records: Hakau 1 (1♀), Ifeylo (1♂).

Note: The female was flying ~0.4 m above a partly dried-up riverbed in dusk. The identification of the female is tentative, since no female descriptions are available for any species of this genus.

***Agyrtacantha microstigma* (Selys, 1878)**
Orr & Kalkman (2015) Waigeo.
New record: Vanlal (1♂). One–two specimens observed patrolling over a small river (stream) in a shady place. The stream is fast-flowing (rhithral), but specimens were observed in the slower flowing section of it.
First record for Misool.

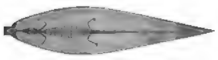
***Anax fumosus* Hagen 1867**
Orr & Kalkman (2015) Batanta, Salawati?.

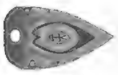
***Anax maclachlani* Förster, 1898**
Orr & Kalkman (2015) Misool; Kovács *et al.* (2021) Batanta.

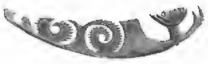
***Gynacantha calliope* Lieftinck, 1953**
Orr & Kalkman (2015) Waigeo.

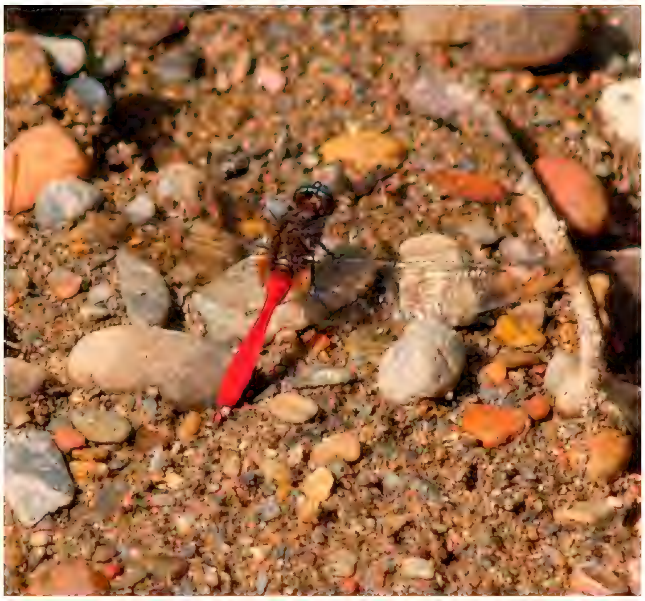
***Gynacantha kirbyi* Krüger, 1899**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool, Waigeo.

***Gynacantha mocsaryi* Förster, 1898**
Orr & Kalkman (2015) Batanta, Salawati, Waigeo; Kovács *et al.* (2015b; 2016; 2021) Batanta.









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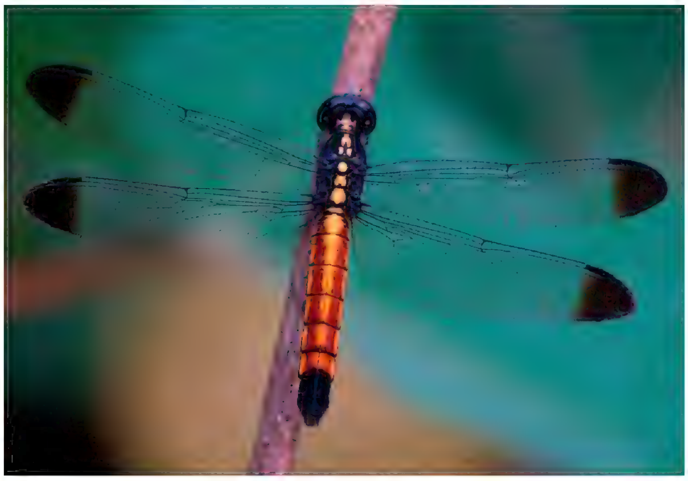

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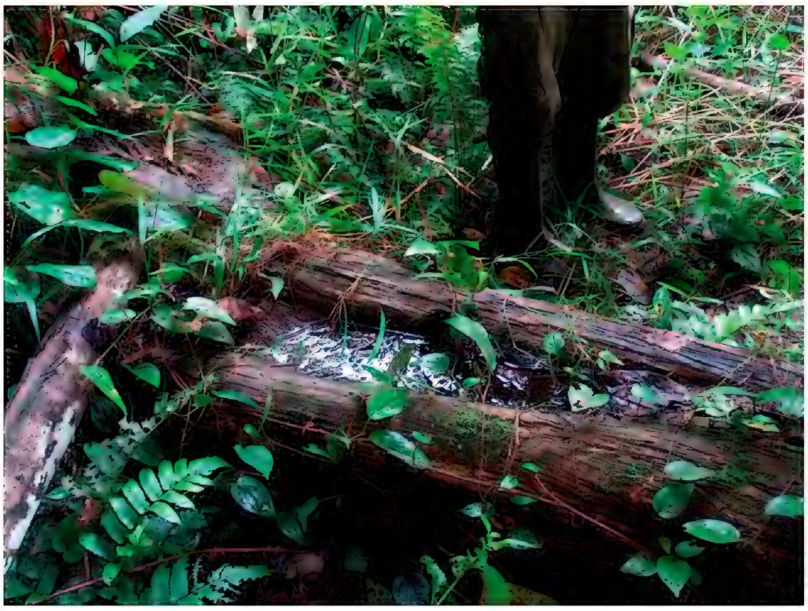

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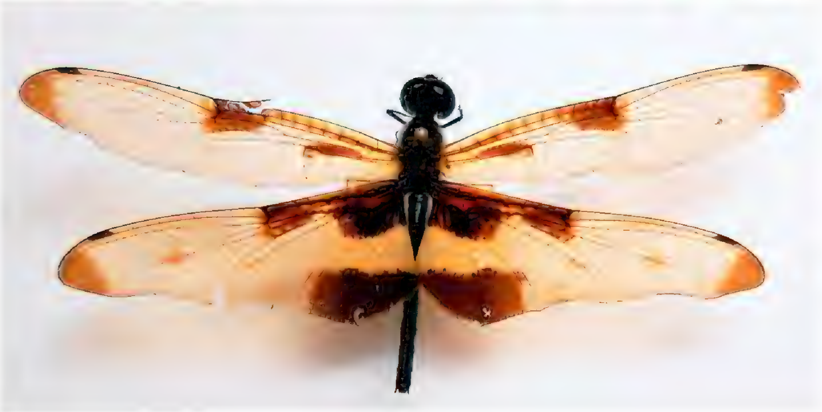

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Figures 6–9. Odonata from Raja Ampat. 6 – *Orthetrum villosovittatum*, ♂ in Aduwey, Misool. The single observed specimen was resting on the ground in a sunny place between bushes in a mosaic landscape; 7 – *Prothorthemis coronata*, ♀ in Aduwey, Misool Island. Adult individuals were resting or flying in shadowy places along a small river in a primary lowland rainforest; 8 – Place of oviposition of *Prothorthemis coronata* - a small hole in a tree trunk filled with water and some dead leaves; 9 – *Rhyothemis phyllis chloe*, ♀ from Waigeo Island.

***Gynacantha rosenbergi* Brauer, 1867**
Kovács *et al.* (2021) Batanta.

Gomphidae Rambur, 1842

***Ictinogomphus lieftincki* (Schmidt, 1934)**
Orr & Kalkman (2015) Batanta, Salawati.

Synthemistidae Tillyard, 1911

***Palaeosynthemis cervula* (Lieftinck, 1938)**
Michalski (2012) Misool; Kovács *et al.* (2021) Batanta, as *Palaeosynthemis* cf. *cervula*.
New record: Vanlal (1♂ & 1♀).

Note: The Misool record of this species was omitted by Orr & Kalkman (2015).

Macromiidae Needham, 1903

***Macromia euphrosyne* Lieftinck, 1952**
Orr & Kalkman (2015) Waigeo; Kovács *et al.* (2015b; 2021) Batanta.

***Macromia hermione* Lieftinck, 1952**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool.

***Macromia sophrosyne* Lieftinck, 1952**
Orr & Kalkman (2015) Waigeo.

Libellulidae Leach, 1815

***Agrionoptera insignis* (Rambur, 1842)**
Orr & Kalkman (2015) Batanta, Salawati; Kovács *et al.* (2015b; 2021) Batanta.
New record: Hakau 2 (1♀).
First record for Misool.

Note: The specimen corresponds to the subspecies *Agrionoptera insignis papuensis*, although according to Michalski (2012) the status of this subspecies is not clear.

***Agrionoptera longitudinalis* Selys, 1878**
Orr & Kalkman (2015) Batanta, Salawati, Waigeo; Kovács *et al.* (2015b; 2016; 2021) Batanta.
New records: Hakau 2 (1♂), Ifeylo (2♂ & 1♀), Vanlal (1♀).
First record for Misool.

Notes: All specimens correspond to the subspecies *Agrionoptera longitudinalis biserialis*. In one case, a female was ovipositing in a small (~10x10x10 cm) hole filled with water and some dead leaves in a stone. The stone was located in a shaded place on the bank of a small forest river (Fig. 3).

***Brachydiplax duivenbodei* (Brauer, 1866)**
Orr & Kalkman (2015) Batanta, Salawati; Kovács *et al.* (2015b; 2016; 2021) Batanta.

***Camacinia gigantea* (Brauer, 1867)**
Orr & Kalkman (2015) Waigeo; Kovács *et al.* (2015b; 2021) Batanta.
New records: Hakau 2 (1♂), Gam (1♂).
First record for Misool.

Notes: Two specimens - one in the gardens of a river valley, one near a village - were resting in sunny places between bushes (Fig. 4). The image of *C. gigantea* (two specimens, image of one male) from Misool Island available on the Insect-Trade.EU website (https://www.insect-trade.eu/?category=odonata&eshop=catalogue&page=4, accessed 27.11.2020).

***Diplacina cyrene* Lieftinck, 1953**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool.

***Diplacina erigone* Lieftinck, 1954**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool.

***Diplacina* cf. *ismene* Lieftinck, 1933**
Kovács *et al.* (2016) Batanta.

***Diplacina micans* Lieftinck, 1953**
Orr & Kalkman (2015) Waigeo.

***Diplacina olahi* Theischinger et Kovács, 2015**
Kovács *et al.* (2015b; 2016) Batanta.

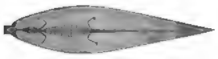
***Diplacina paula* Ris, 1919**
Michalski (2012) Misool, as *Diplacina paula lethe*; Orr & Kalkman (2015) Misool.

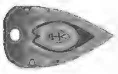
***Diplacina smaragdina* Selys, 1878**

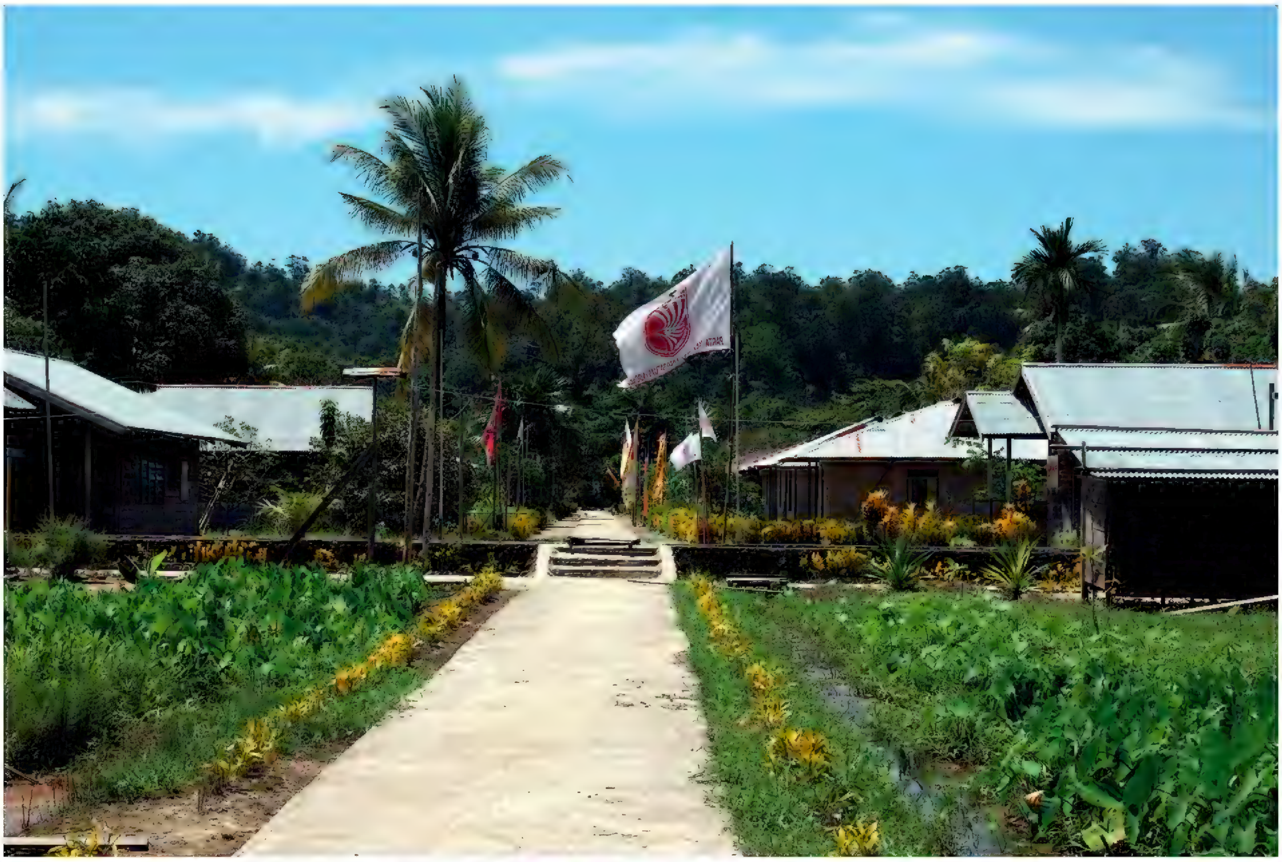
Note: As stated by Kovács *et al.* (2021), all records of *Diplacina olahi* by Kovács *et al.* (2016) in fact refer to *Diplacina smaragdina*.

***Diplacodes trivialis* (Rambur, 1842)**
Kovács *et al.* (2015b; 2016; 2021) Batanta.
New record: Waisai 3 (4♀).
First record for Waigeo.

***Huonia epinephela* Förster, 1903**
Kovács *et al.* (2015b; 2016; 2021) Batanta.







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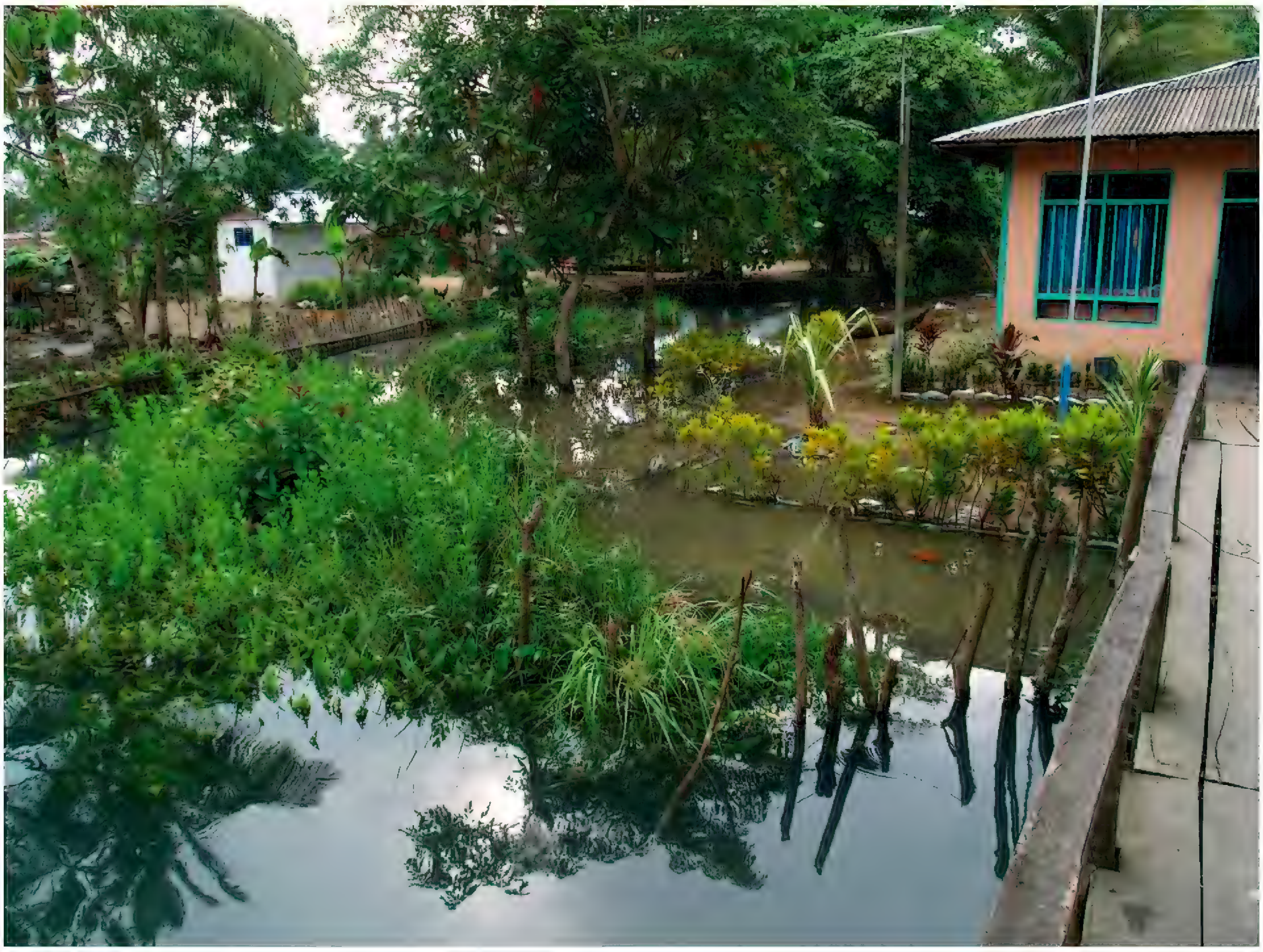

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Figures 10–11. The habitat of *Agriocnemis femina* in Aduwey village, Misool Island, Raja Ampat. 10 – Small ditches along the foothpath, with dense, partially submerged aquatic vegetation (image courtesy Dmitry Telnov); 11 – Ditches near the backyard garden during high tide, with seawater overflowing the ditches.

Huonia silvicola **Lieftinck, 1942**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool.

Huonia thais **Lieftinck, 1953**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool; Kovács *et al*. (2015b; 2021) Batanta.

Huonia thisbe **Lieftinck, 1953**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool.

Hydrobasileus brevistylus **(Brauer, 1865)**
New record: Hakau 2 (1♂ & 1♀).
First record for Misool and Raja Ampat Islands.

Note: Specimens observed in copula near a small pool in a river valley (Fig. 5).

Hydrobasileus vittatus **Kirby, 1889**
Orr & Kalkman (2015) Batanta; Kovács *et al*. (2015b; 2021) Batanta.

Lyriothemis hirundo **Ris, 1913**
Orr & Kalkman (2015) Batanta, Salawati.

Lyriothemis meyeri **(Selys, 1878)**
Orr & Kalkman (2015) Batanta, Salawati, Waigeo.

Nannophlebia amnosia **Lieftinck, 1955**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool; Kovács *et al*. (2015b; 2016; 2021) Batanta.

Nannophlebia amphycillis **Lieftinck, 1933**
Kovács *et al*. (2021) Batanta.

Note: Records of *Nannophlebia amnosia* by Kovács *et al*. (2016) now refer to *Nannophlebia amphycillis* (see Kovács *et al*. 2021).

Nannophya pygmaea **Rambur, 1942**
Kovács *et al*. (2016; 2021) Batanta, as *Nannophya* cf. *pygmaea*.
New record: Aduwey (1♂).
First record for Misool.

Nesoxenia mysis **(Selys, 1878)**
Michalski (2012) Misool; Orr & Kalkman (2015) Misool, Waigeo; Kovács *et al*. (2021) Batanta.
New records: Hakau 2 (1♀ (teneral)), Ifeylo (2♂), Aduwey (1♂), Lilinta (5♂ & 3♀), Gam (2♂).

Note: All specimens correspond with the nominate subspecies *N. mysis mysis*.

Neurothemis ramburii **(Brauer, 1866)**
Kovács *et al*. (2015b; 2016; 2021) Batanta.

Neurothemis stigmatizans **(Fabricius, 1775)**
Michalski (2012) Salawati, subspecies *manadensis*; Orr & Kalkman (2015) Batanta, Misool, Salawati, Waigeo; Kovács *et al*. (2015b; 2016; 2021) Batanta.
New records *Neurothemis stigmatizans bramina*: Hakau 1 (1♂), Hakau 2 (1♂), Ifeylo (1♂), Aduwey (3♂), Lilinta (1♂ (teneral) 2♀), Gam (2♂), Gam* (3♂), Waisai 1 (1♂).
New records *Neurothemis stigmatizans manadensis*: Hakau 2 (1♂), Polee (1♂ & 1♀).

Notes: According to Michalski (2012), *N. stigmatizans manadensis* is only known so far from western New Guinea and Maluku. The female from Polee was a heterochrome (hyaline) form. According to Michalski (2012), only homeochrome form females are known for this subspecies. *Neurothemis stigmatizans manadensis* (two females, an image of one specimen) from Misool Island are available on the Insect-Trade.EU website (https://www.insect-trade.eu/?category=odonata&eshop=catalogue&page=3, accessed 27.11.2020). Although the subspecies have been described and illustrated (Michalski 2012), relatively large differences in colouring have been found in the material already analysed. Therefore, in the present paper, not all of these subspecies are recognised as separate taxa.

Orthetrum serapia **Watson, 1984**
Kovács *et al*. (2015b; 2021) Batanta.
New records: Hakau 2 (1♂), Aduwey (2♂).
First record for Misool.

Orthetrum villosovittatum **(Brauer, 1868)**
Orr & Kalkman (2015) Batanta, Salawati; Kovács *et al*. (2015b; 2021) Batanta.
New records: Hakau 1 (2♂ & 1♀), Hakau 2 (4♂).
First record for Misool.

Note: One male patrolling over a small pool in gardens in a river valley (Fig. 6).

Pantala flavescens **(Fabricius, 1798)**
Kovács *et al*. (2021) Batanta.
New records: Hakau 2 (1♀), Aduwey (6♂ & 2♀).
First record for Misool.

Protorthemis coronata **(Brauer, 1866)**
Orr & Kalkman (2015) Batanta, Salawati, Waigeo; Kovács *et al*. (2015b; 2021) Batanta.
New records: Hakau 1 (2♀), Hakau 2 (4♂ & 1♀), Ifeylo (2♂ & 1♀), Lilinta (1♂), Vanlal (1♂).
First record for Misool.

Notes: Common species in river valleys, but occasionally observed in villages. In two cases females were observed ovipositing in small (~15 x 50 x 7 cm and ~10 x 15 x 5 cm) holes in tree trunks filled with water and some dead leaves. One of the tree trunks was located on a small forest path, relatively far from watercourses, and the second one was on the bank of a small forest river, both in shaded places. In several cases males were observed, patrolling or perching near shallow puddles in shaded parts of a forest (Figs 7–8). An image of a female *P. coronata* from Waigeo Island was available on the Insect-Trade. EU website (https://www.insect-trade.eu/?category=odonata&eshop=catalogue&page=5, accessed 27.11.2020).

Raphismia bispina **(Hagen, 1867)**
Orr & Kalkman (2015) Misool; Kovács *et al*. (2015b; 2016; 2021) Batanta.

Rhodothemis nigripes **Lohmann, 1984**
Kovács *et al*. (2021) Batanta.

Rhyothemis phyllis **Sulzer, 1776**
Kovács *et al*. (2015b; 2016; 2021) Batanta.
New records: Waisai 3 (1♀).
First record for Waigeo.

Notes: The Waisai specimens correspond to *R. phyllis chloe* Kirby, 1894 (Fig. 9) so far known only from Aru Islands and North Australia to Brisbane (Theischinger & Hawking 2006; Michalski 2012). An image of *R. phyllis chloe* (male) from Waigeo Island was available on the Insect-Trade.EU website (https://www.insect-trade.eu/?category=odonata&eshop=catalogue&page=7, accessed 27.11.2020).

Rhyothemis **regia (Brauer, 1867)**
Kovács *et al*. (2021) Batanta.

Rhyothemis **resplendens Selys, 1878**
Orr & Kalkman (2015) Batanta, Salawati; Kovács *et al*. (2016; 2021) Batanta.

Rhyothemis **rita Kovács et Theischinger, 2016**
Kovács *et al*. (2016) Batanta.

Tetrathemis irregularis **Brauer, 1868**
Orr & Kalkman (2015) Misool; Kovács *et al*. (2021) Batanta.

Tramea eurybia eurybia **Selys, 1878**
Orr & Kalkman (2015) Misool; Kovács *et al*. (2015b; 2021) Batanta, reported as *Tramea eurybia* s. l., subspecies identification not provided.

Tramea transmarina propinqua **Lieftinck, 1942**
Kovács *et al*. (2021) Batanta.

Zyxomma multinervorum **Charpenter, 1897**
Kovács *et al*. (2021) Batanta.

Discussion

There are about 6000 species of dragonflies known worldwide. Of these, about 620 species are found in New Guinea, Maluku and the Solomon Islands (Michalski 2012) and about 490 in New Guinea itself (Orr & Kalkman 2015). As several new species are described from this region each year, the total number of species is already significantly higher. A total of 103 species of dragonflies are currently known from Raja Ampat, 50 Zygoptera and 53 Anisoptera (Table 1).

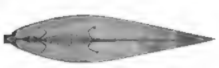
Information about four species of dragonflies was found on and insect trader website. According to the information on the website, all insects are accompanied with complete collecting data, often including altitude, latitude, and longitude. As no specimens were purchased, the exact locality details are not known, but it is known that some commercial specimens can have unreliable or incomplete, or even incorrect data. However, such specimens are also used in research, including in this case; the information given on the website does not contradict the data obtained from other research.

Summarizing published and previously unpublished data, 21 Zygoptera species and 27 Anisoptera species are currently known for the fauna of Misool, for a total of 48 species. Although the number of species has increased, the Misool fauna can still only be considered as satisfactorily studied, and it is likely that a relatively large number of additional species remain to be discovered on the island. This is supported by the small number of research expeditions and the limited time spent on research, as well as the absence on Misool of various species or groups of species found on nearby islands. The current proportion of species in the suborders, Zygoptera 52% and Anisoptera 48%, indicates an incomplete knowledge of the Zygoptera fauna in Misool and Waigeo, too. For example, in New Guinea – Zygoptera represent 62% and Anisoptera 38% of dragonfly diversity (Kalkman & Orr 2013; Orr & Kalkman 2015).

The small number of species found for each observation site, confirms that the studies of all islands are incomplete. For example, in a ~2.5 km^2 area in a lower montane forest of Papua New Guinea, 61 species were found during an 8–9 month observation period; however, most species occurred in small numbers (Oppel 2005). In another study, which compared natural (~2.5 km^2) and modified (~4 km^2) rainforest areas, 78 species were found, with a very high ratio of Zygoptera vs Anisoptera; 73–76% and 24–27% respectively (Oppel 2006).

Table 1. The currently known dragonflies in Raja Ampat with notes on the level of endemism. Legends: E – endemic species for the Papuan region in strict sense; E* – endemic species, recorded only from one island; ? – species marked with "?" by previous authors).

Genus	Species	Author	Waigeo	Misool	Batanta & Salawati	Batanta	Kofiau	Raja Ampat
Zygoptera								
Argiolestidae								
Argiolestes	*australis*	Guerin, 1832	E			E		x
Argiolestes	*varga*	Kovács et Theischinger, 2021				E*		x
Metagrion	*coartans*	Lieftinck, 1956	E					x
Metagrion	*ochrostoma*	Lieftinck, 1949	E*					x
Metagrion	sp.					x		
Podopteryx	*selysi*	Förster, 1899	x		x			x
Calopterygidae								
Neurobasis	*australis australis*	Selys, 1897	x		x	x		x
Neurobasis	*australis misoolensis*	Lieftinck, 1955		E*				x
Chlorocyphidae								
Rhinocypha	*tincta sagitta*	Lieftinck, 1938		x	x	x		x
Rhinocypha	*tincta tincta*	Rambur, 1842	E*					x
Coenagrionidae								
Agriocnemis	*femina*	Brauer, 1868	x	x		x		x
Archibasis	*mimetes*	Tillyard, 1913	x	x	x			x
Argiocnemis	*rubescens*	Selys, 1877				x		x
Ceriagrion	*aeruginosum*	Brauer, 1869				x		x
Ischnura	*senegalensis*	Rambur, 1842				x		x
Papuagrion	*magnanimum*	Selys, 1876				E		x
Pseudagrion	*civicum*	Lieftinck, 1932				E		x
Pseudagrion	*starreanum*	Lieftinck, 1949			E	E		x
Teinobasis	*michalskii*	Theischinger et Kalkman, 2014		E*				x
Teinobasis	*prothoracica*	Selys, 1877	E	E				x
Teinobasis	*rufithorax*	Selys, 1877	x	x	x	x		x
Teinobasis	*superba*	(Hagen in Selys, 1877)		E?		E		x
Teinobasis	*wallacei*	Campion, 1924		E				x
Xiphiagrion	*cyanomelas*	Selys, 1876				x		x
Isostictidae								
Selysioneura	*cornelia*	Lieftinck, 1953		E		E		x
Tanymecosticta	*jejuna*	Lieftinck, 1959		E				x
Lestidae								
Indolestes	*albicaudus*	McLachlan, 1895		E				x
Platycnemididae								
Idiocnemis	*bidentata*	Selys, 1878	E		E	E		x



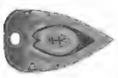


Table 1 (continuation)

Idiocnemis	*dagnyae*	Lieftinck, 1958		E				x
Idiocnemis	*fissidens*	Lieftinck, 1958	E*					x
Idiocnemis	*inornata*	Selys, 1878				E		x
Idiocnemis	*strumidens*	Lieftinck, 1958		E		E		x
Nososticta	*atrocyana*	Lieftinck, 1960	E*					x
Nososticta	*aurantiaca*	Lieftinck, 1938			E	E		x
Nososticta	*dora*	Kovács et Theischinger 2016				E*		x
Nososticta	*erythroprocta*	Selys, 1886	E*					x
Nososticta	*evelynae*	Lieftinck, 1960	E*					x
Nososticta	*nigrifrons*	(Ris,1913)		E				x
Nososticta	*plagiata*	Selys, 1886		E				x
Nososticta	*pyroprocta*	Lieftinck, 1960		E				x
Nososticta	*rufipes*	Theischinger et Kalkman, 2014		E				x
Nososticta	*xanthe*	Lieftinck, 1938		E	E			x
Palaiargia	*charmosyna*	Lieftinck, 1932				E		x
Palaiargia	*melidora*	Lieftinck, 1953	E*					x
Palaiargia	*micropsitta*	Lieftinck, 1957		E*				x
Palaiargia	*nasiterna*	Lieftinck, 1938	E					x
Palaiargia	*susannae*	Kovács et Theischinger 2015				E*		x
Platystictidae								
Drepanosticta	*auriculata*	Selys, 1878				E		x
Drepanosticta	*batanta*	Kovács et Theischinger 2015				E*		x
Drepanosticta	*inconspicua*	Lieftinck, 1938	E					x
Drepanosticta	*misoolensis*	van Tol, 2007		E*				x
Anisoptera								
Aeshnidae								
Agyrtacantha	*dirupta*	(Karsch, 1889)		x		x		x
Agyrtacantha	*microstigma*	(Selys, 1878)	x	x				x
Anax	*fumosus*	Hagen, 1867			x?			x?
Anax	*maclachlani*	Förster, 1898		x		x		x
Gynacantha	*calliope*	Lieftinck, 1953	E*					x
Gynacantha	*kirbyi*	Krüger, 1899	x	x				x
Gynacantha	*mocsaryi*	Förster, 1898	x		x	x		x
Gynacantha	*rosenbergi*	Brauer, 1867				x		x
Gomphidae								
Ictinogomphus	*lieftincki*	(Schmidt, 1934)			x			x
Synthemistidae								
Palaeosynthemis	*cervula*	(Lieftinck, 1938)		E		E?		x
Macromiidae								
Macromia	*euphrosyne*	Lieftinck, 1952	E			E		x
Macromia	*hermione*	Lieftinck, 1952		E*				x
Macromia	*sophrosyne*	Lieftinck, 1952	E*					x
Libellulidae								
Agrionoptera	*insignis*	(Rambur, 1842)		x	x	x		x
Agrionoptera	*longitudinalis*	Selys, 1878	x	x	x	x		x
Brachydiplax	*duivenbodei*	(Brauer, 1866)			x	x		x
Camacinia	*gigantea*	(Brauer, 1867)	x	x		x		x
Diplacina	*cyrene*	Lieftinck, 1953		E				x
Diplacina	*erigone*	Lieftinck, 1954		E				x
Diplacina	*ismene*	Lieftinck, 1933				E?		x?
Diplacina	*micans*	Lieftinck, 1953	E*					x
Diplacina	*olahi*	Theischinger et Kovács, 2015				E*		x

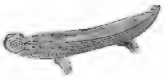
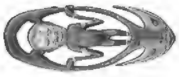
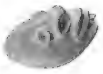
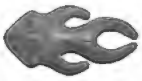





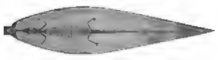
Table 1 (continuation)

Diplacina	*paula*	Ris, 1919		E*				x
Diplacina	*smaragdina*	Selys, 1878				E		x
Diplacodes	*trivialis*	(Rambur, 1842)	x			x		x
Huonia	*epinephela*	Förster, 1903				E		x
Huonia	*silvicola*	Lieftinck, 1942		E				x
Huonia	*thais*	Lieftinck, 1953		E		x		x
Huonia	*thisbe*	Lieftinck, 1953		E*				x
Hydrobasileus	*brevistylus*	(Brauer, 1865)		x				x
Hydrobasileus	*vittatus*	Kirby, 1889			x	x		x
Lyriothemis	*hirundo*	Ris, 1913			x			x
Lyriothemis	*meyeri*	(Selys, 1878)	E		E			x
Nannophlebia	*amnosia*	Lieftinck, 1955		E		x		x
Nannophlebia	*amphicyllis*	Lieftinck, 1933				E		x
Nannophya	*pygmaea*	Rambur, 1942		x		x		x
Nesoxenia	*mysis*	(Selys, 1878)	x	x		x		x
Neurothemis	*ramburii*	(Brauer, 1866)				x		x
Neurothemis	*stigmatizans*	(Fabricius, 1775)	x	x	x	x		x
Orthetrum	*serapia*	Watson, 1984		x		x		x
Orthetrum	*villosovittatum*	(Brauer, 1868)		x	x	x		x
Pantala	*flavescens*	(Fabricius, 1798)		x		x		x
Protorthemis	*coronata*	(Brauer, 1866)	x	x	x	x		x
Raphismia	*bispina*	(Hagen, 1867)		x		x		x
Rhodothemis	*nigripes*	Lohmann, 1984				E		x
Rhyothemis	*phyllis*	Sulzer, 1776	x			x		x
Rhyothemis	*regia*	(Brauer, 1867)				x		x
Rhyothemis	*resplendens*	Selys, 1878			x	x		x
Rhyothemis	*rita*	Kovács et Theischinger 2016				E*		x
Tetrathemis	*irregularis*	Brauer, 1868		x		x		x
Tramea	*eurybia eurybia*	Selys, 1878		x		x		x
Tramea	*transmarina propinqua*	Lieftinck, 1942				x		x
Zyxomma	*multinervorum*	Carpenter, 1897				E		x
Total number of species			**33**	**48**	**22**	**62**	**0**	**103**

Of all Raja Ampat Odonata species, 62 species (60%) are endemic to the Papuan Region in a strict sense. Twenty-three of these species can be considered as local endemics, as these species are known from only one of the Raja Ampat islands, and there are no records from other islands, including New Guinea (Table 1). It is possible that as the level of research in the region increases, some of the locally endemic species may be found elsewhere over time. However, given the relatively small ranges of most species in this area, these species are likely to remain endemic to the Papuan region in a strict sense.

As a result of comprehensive research (Polhemus *et al*. 2004) 40 areas of freshwater endemism have been defined on New Guinea and nearby islands, grouped into 6 broad regions. The Raja Ampat Archipelago is one of the above regions of broad endemism. Waigeo, Batanta, and Misool are defined as separate areas of endemism. At the same time, there is no strong justification for the division of Salawati, with the southern part of Salawati being included in the Vogelkop Lowlands area, while the northern part (Wagon Mountains) could potentially be included in the Batanta area. Kofiau is not included in any area.

The same study mentions taxa defining areas of endemism. Although it is not clearly defined why only Zygoptera species have been used to characterize areas of endemism, this may be explained by the fact that Anisoptera as a whole have better dispersal abilities. In the light of current knowledge on the distribution of Odonata species in the Papuan Region, clarifications are proposed to the list of taxa defining areas of endemism, including Anisoptera species (Table 2).



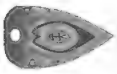


Table 2. Proposals for the list of taxa defining areas of endemism.
Legends: Species are listed in alphabetical order, first mentioning Zygoptera, and then Anisoptera. The left column of the table shows the species names used by Polhemus *et al*. (2004), and the right column shows current species names.

Taxa defining areas of endemism as proposed by Polhemus *et al*. (2004)	**Proposals for updating the list of taxa defining areas of endemism**
Waigeo area	
Argiolestes coartans	*Metagrion coartans*
Argiolestes ochrostomus	*Metagrion ochrostoma*
Idiocnemis fissidens	*Idiocnemis fissidens*
Nososticta atrocyana	*Nososticta atrocyana*
Nososticta erythroprocta	*Nososticta erythroprocta*
Nososticta evelynae	*Nososticta evelynae*
Palaiargia nasisterna [sic! *nasiterna*]	Exclude from list. *Palaiargia nasiterna* also reported from West New Guinea
	Palaiargia melidora
Teinobasis prothoracica	Exclude from list. Species also reported from West New Guinea and Misool
	Gynacantha calliope
	Macromia sophrosyne
	Diplacina micans
Batanta area (Salawati not included)	
Not suggested	
	Argiolestes varga
	Drepanosticta batanta
	Nososticta dora
	Palaiargia susannae
	Diplacina olahi
	Rhyothemis rita
Misool area	
'*Argiolestes pyroprocta*'	The name '*Argiolestes pyroprocta*' was never published and is *nomen nudum*
	Drepanosticta misoolensis
Nososticta pyroprocta	Exclude from list. Species also reported from West New Guinea
Palaiargia micropsitta	*Palaiargia micropsitta*
	Teinobasis michalskii
	Macromia hermione
	Diplacina paula
	Huonia thisbe
Vogelkop Lowlands area	**Salawati area**
Argiolestes connectens	*Metagrion connectens* not yet found in Raja Ampat
Argiolestes fontinalis [sic! *fontinale*]	*Metagrion fontinale* not yet found in Raja Ampat
Drepanosticta classeni [sic! *claaseni*]	*Drepanosticta claaseni* not yet found in Raja Ampat
Nososticta xanthe	Exclude from list. Species also found on Misool
Palaiargia eos	Species not yet found in Raja Ampat
Teinobasis micans	Species not yet found in Raja Ampat

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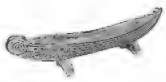
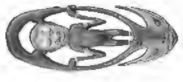

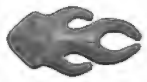

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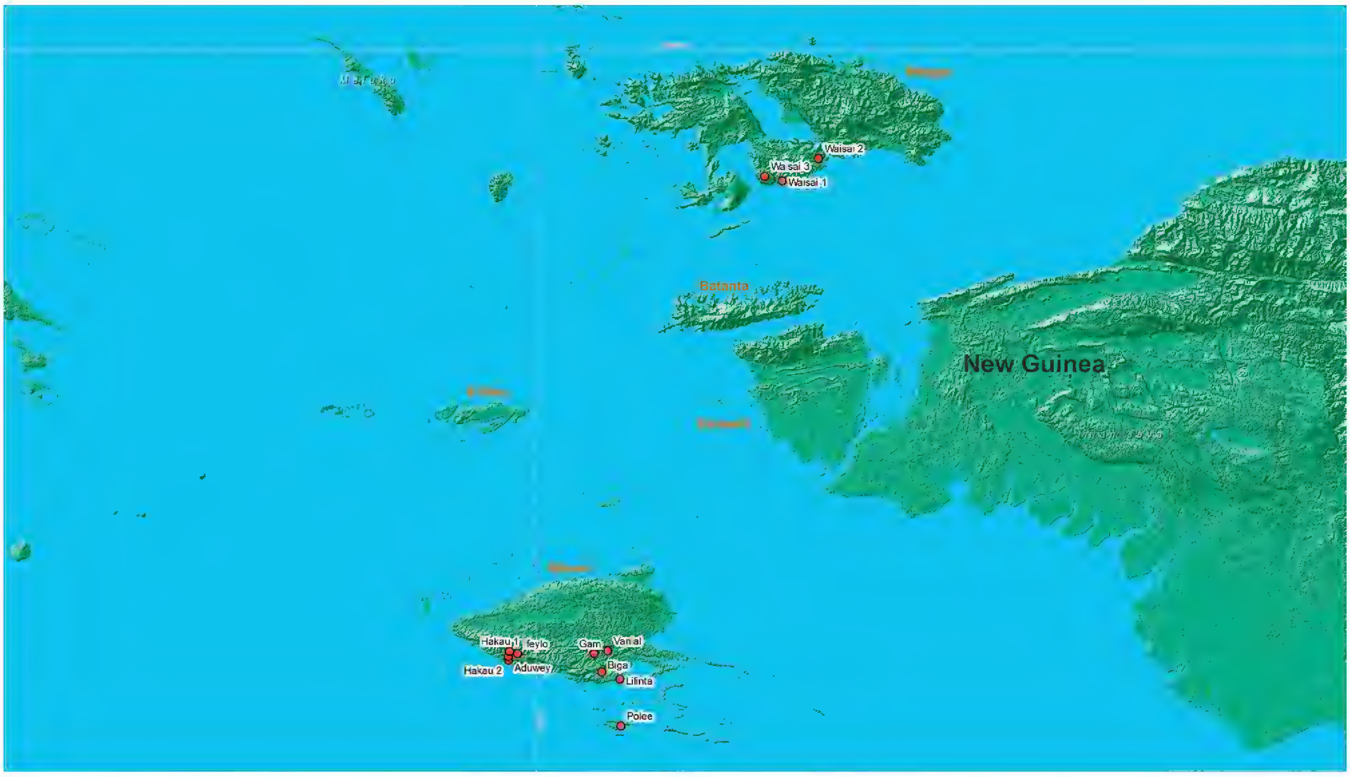
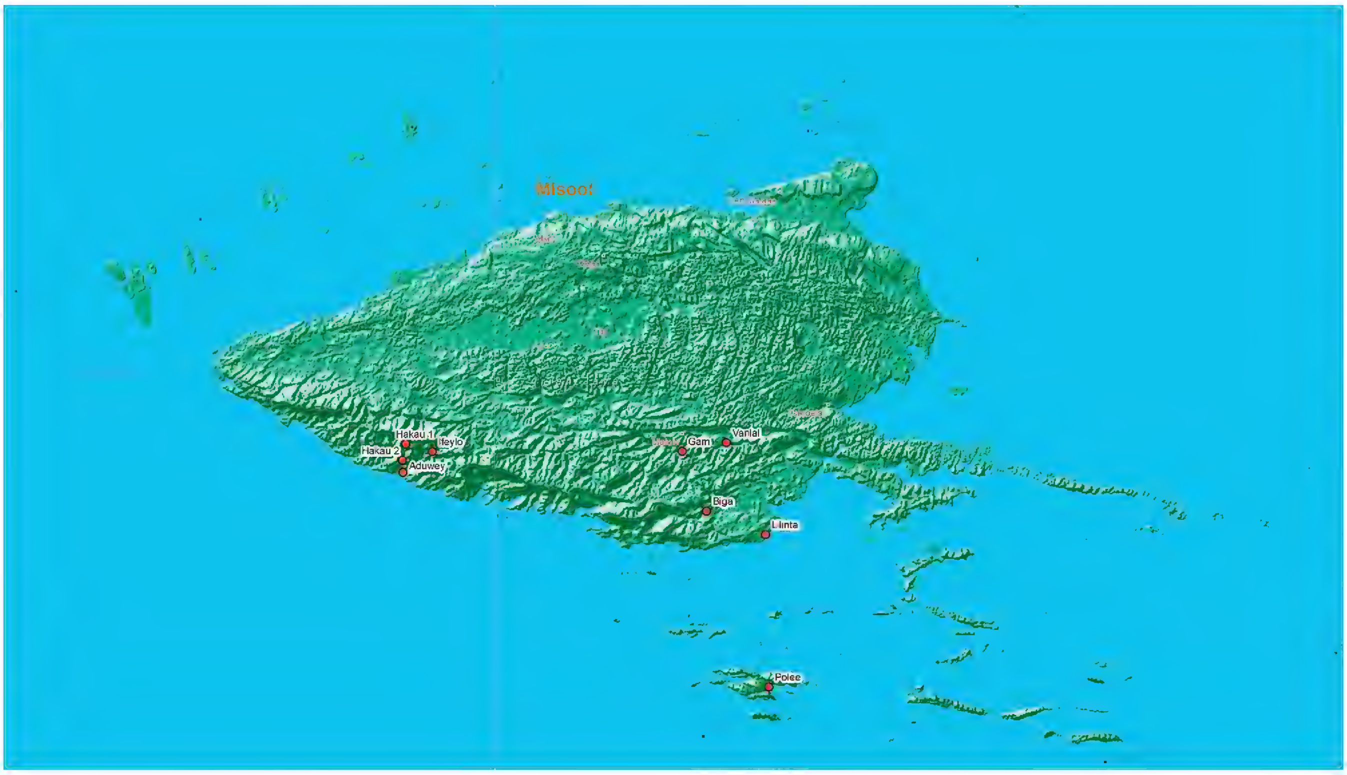
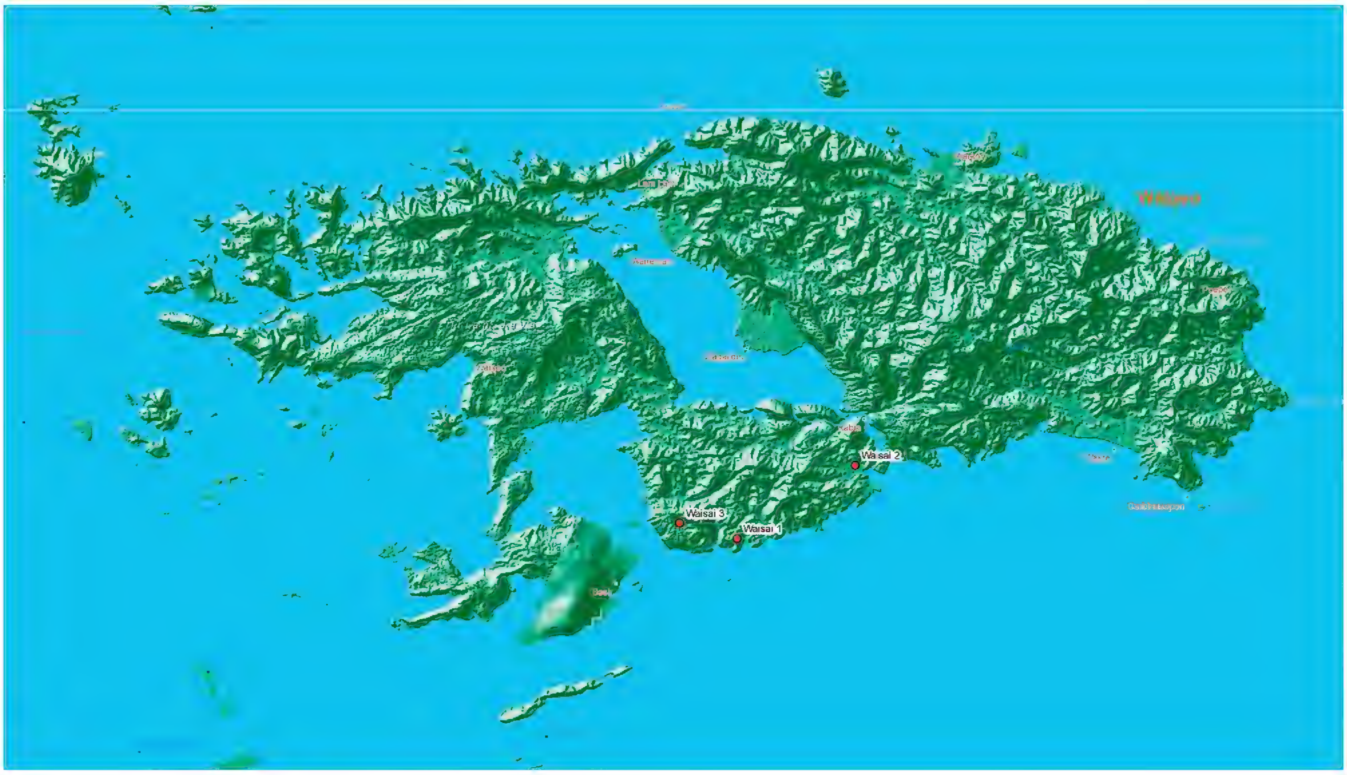


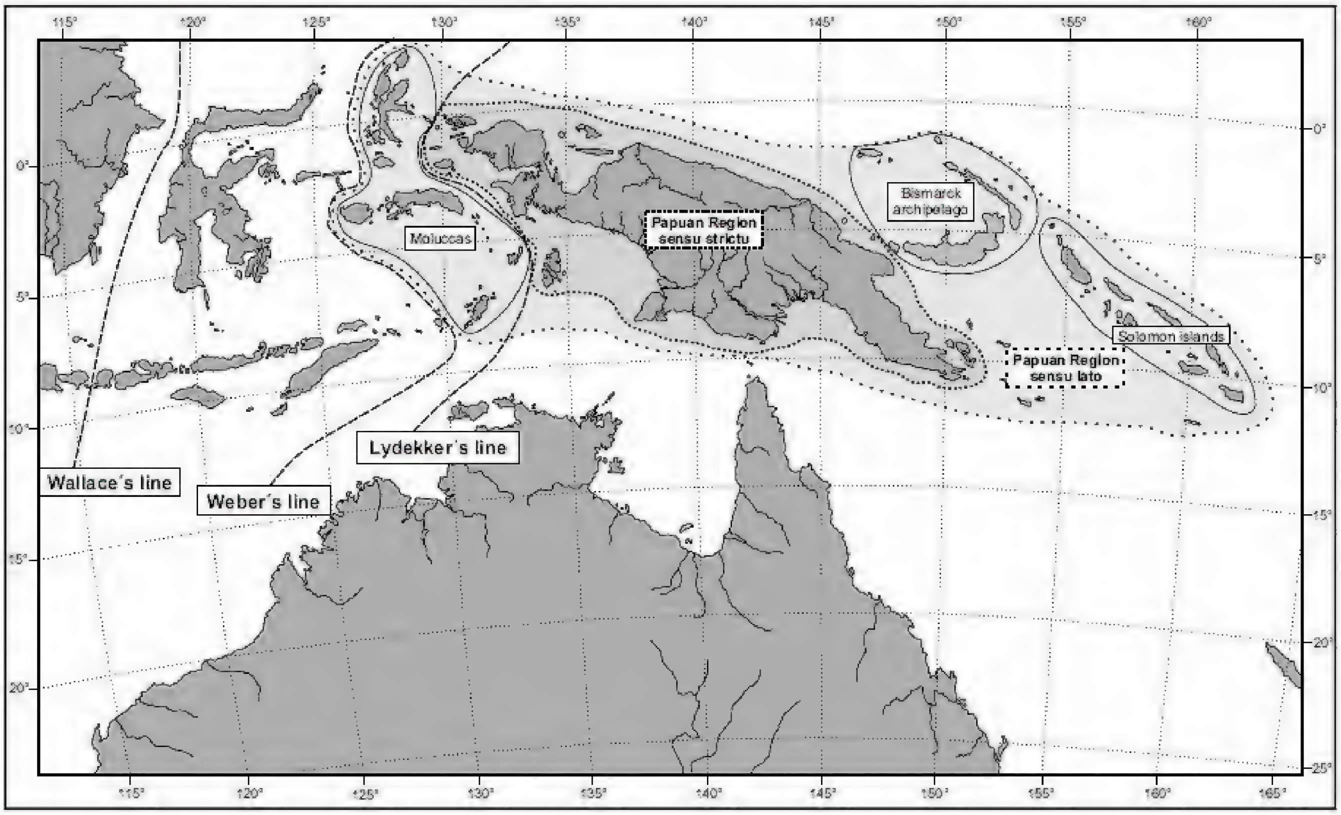
Map 1. The Raja Ampat Islands and localities mentioned in the text on the imagery and shaded relief map (ESRI Data & Maps 2006) (prepared with ArcGIS 10.3).



Map 2. Misool and its adjacent islands and localities mentioned in the text on the imagery and shaded relief map (ESRI Data & Maps 2006) (prepared with ArcGIS 10.3).



Map 3. Waigeo and its adjacent islands and localities mentioned in the text on the imagery and shaded relief map (ESRI Data & Maps, 2006) (prepared with ArcGIS 10.3).



Map 4. The Papuan region in strict and broad senses and the surrounding regions, showing important zoogeographic lines (redrawn from the Times Atlas of the World (1994), with modifications by Riedel (2002)).